

# Status of SPARC

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ARPA-e fusion summit  
Boston  
June 15<sup>th</sup> 2023



Commonwealth  
Fusion Systems

# Status of CFS



- Funded to get to fusion energy as fast as possible
- “Fusion systems company” designed to deliver fusion power plants at scale
- In the last year, CFS has:
  - Grown from approximately 300 employees to more than 500 employees
  - Opened Devens campus with CFS HQ and SPARC
- Company includes a diversity of backgrounds



# CFS Roadmap to Commercial Fusion Energy



Building on tokamak physics demonstrated in machines around the world

**COMPLETED:**  
Demonstrate groundbreaking HTS magnets

**CONSTRUCTION UNDERWAY for 2025 COMPLETION:**  
SPARC  $Q > 1$   
Achieve net fusion energy

**EARLY 2030s:**  
ARC deployed  
~400 MWe



Net fusion energy in a system that scales to a commercial plant



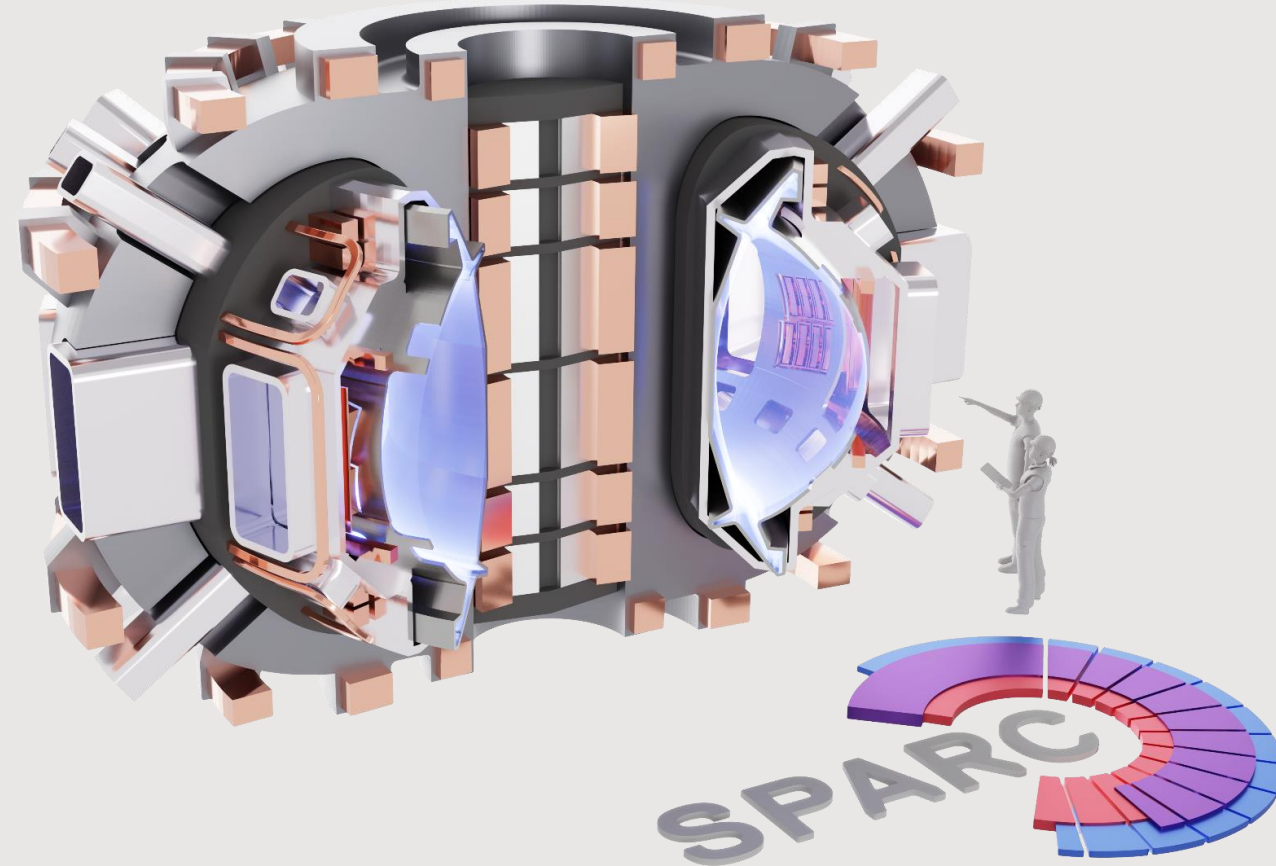
Carbon-free commercial power on the grid



# SPARC Goals



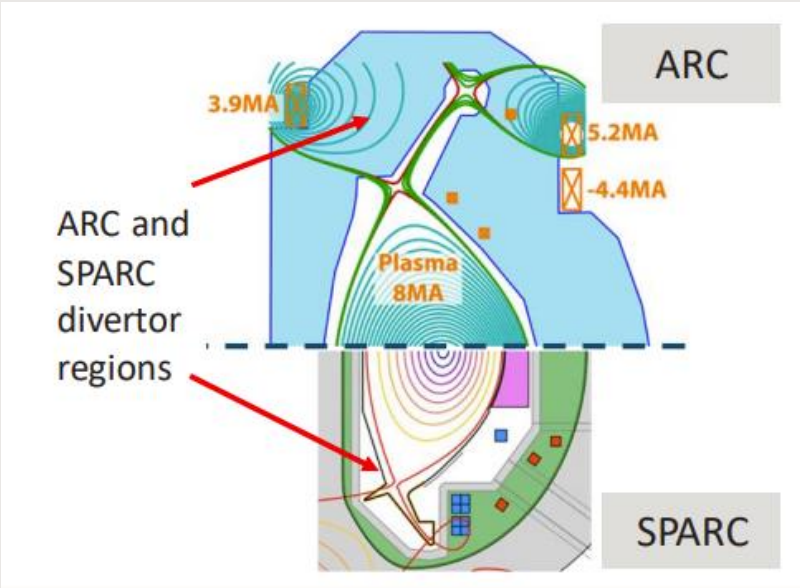
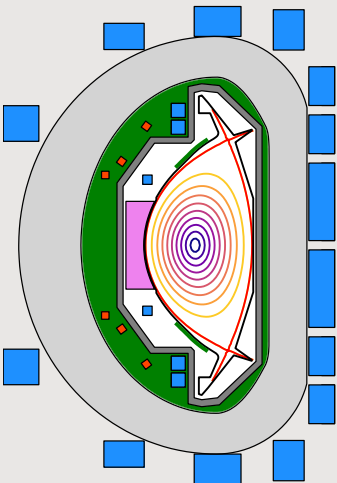
- $Q > 1$  (L-mode first campaign)
- $Q > 10$  (H-mode  $\sim 3^{\text{rd}}$  campaign)
  - Not “Q DT equivalent”—it will actually make and measure fusion and heating power
- $P_{\text{fusion}}$  of 100 MW for 10 seconds
- Demonstrate plasma power exhaust at reactor relevant conditions
- Close ARC physics gaps
- Show CFS can execute a fully integrated fusion system at speed, cost, and scale



# SPARC Technical Details



- Fully D-T capable
- ICRF heated up to 24MW
- Tungsten walls
- Advanced divertor
- Flexible actuators

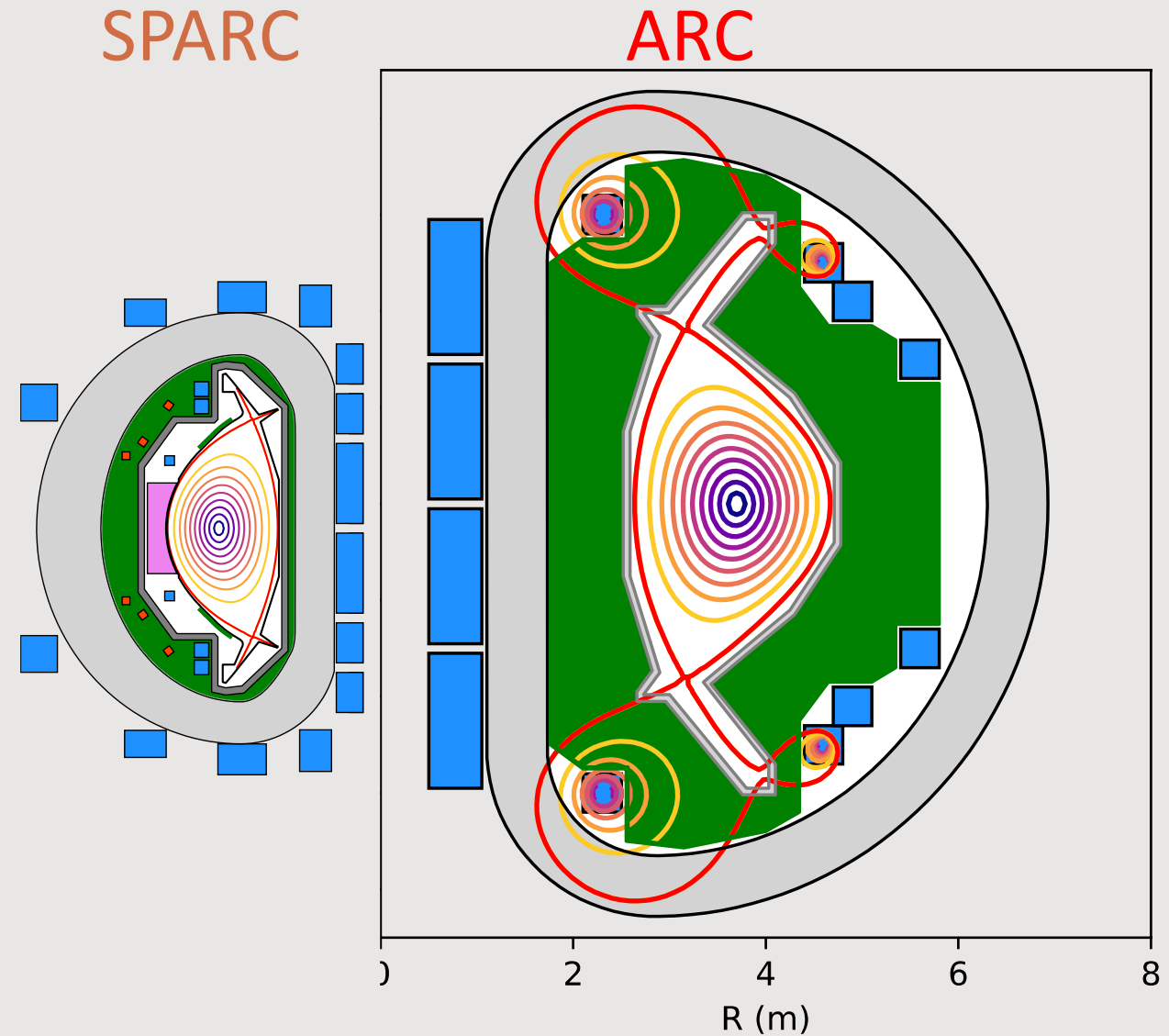


SPARC Primary Reference Discharge		
R	1.85	m
a	0.57	m
B <sub>0</sub>	12.2	T
I <sub>p</sub>	8.7	MA
q <sup>*</sup>	3.05	(q <sub>95</sub> = 3.4)
κ <sub>sep</sub>	1.98	
<T <sub>e</sub> >	7.33	keV
<n <sub>e</sub> >	3.13	10 <sup>20</sup> m <sup>-3</sup>
τ <sub>E</sub>	0.77	s
f <sub>g</sub>	0.37	
P <sub>ohmic</sub>	1.7	MW
P <sub>rf,coupled,operating</sub>	11.1	MW
P <sub>fus</sub>	141	MW
Q	11.0	

# SPARC Places ARC in Context



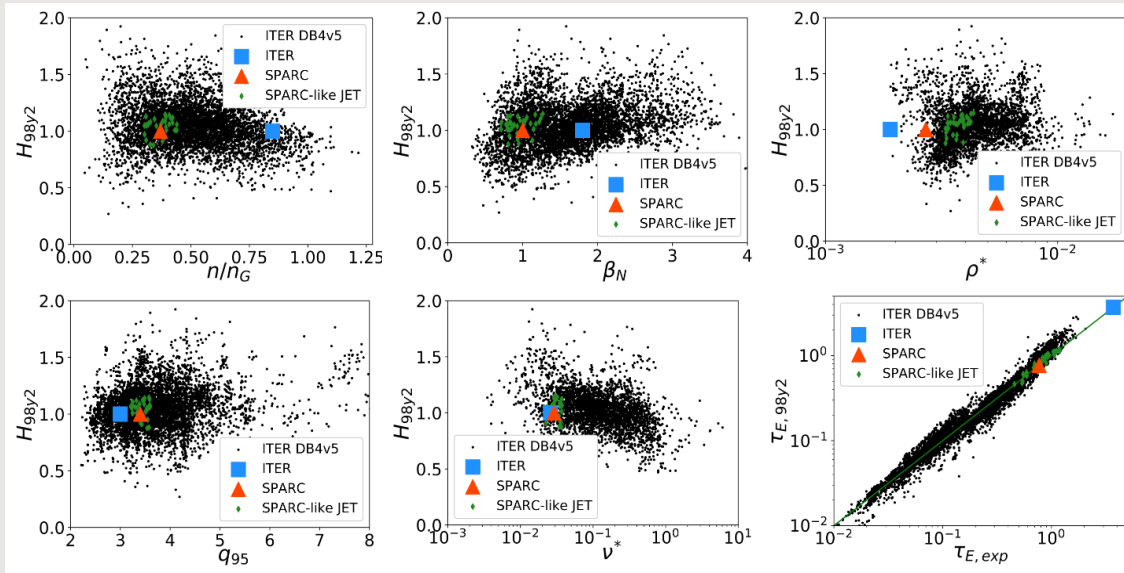
- Most SPARC subsystems are:
  - at nearly full scale
  - delivered commercially with a supply chain that can scale
- Show techno-economic pathway
  - Receipts for costs
- The plant efficiencies needed for a power plant
  - If SPARC had a BOP and blanket it would be  $\sim +30$  MW electric
- Blanket, materials, and tritium processing done in parallel
  - Separable system problems



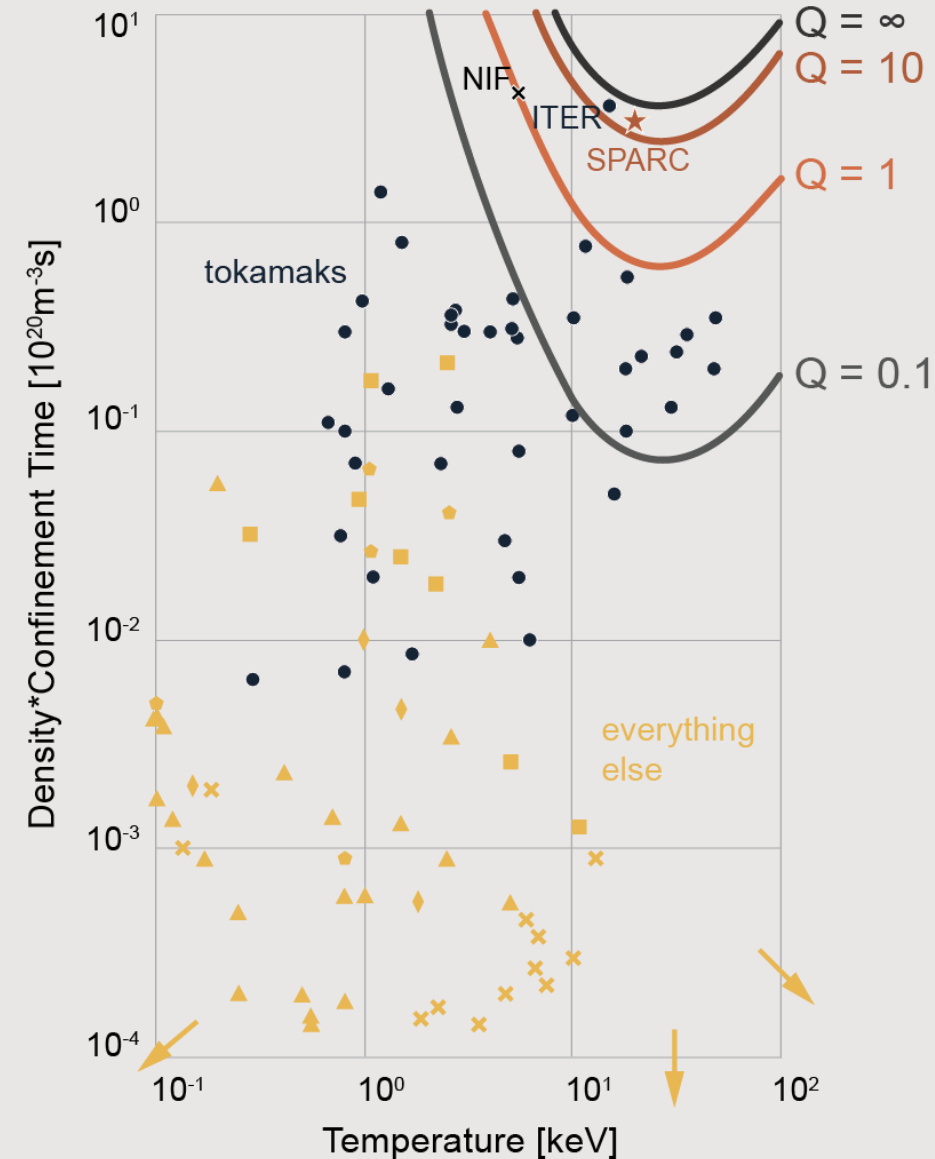
# SPARC Physics Basis Mature and Published



- Peer-reviewed assumptions
- Based on tokamak database
- Validated by simulations
- Will be used to close remaining tokamak gaps at power plant relevant conditions



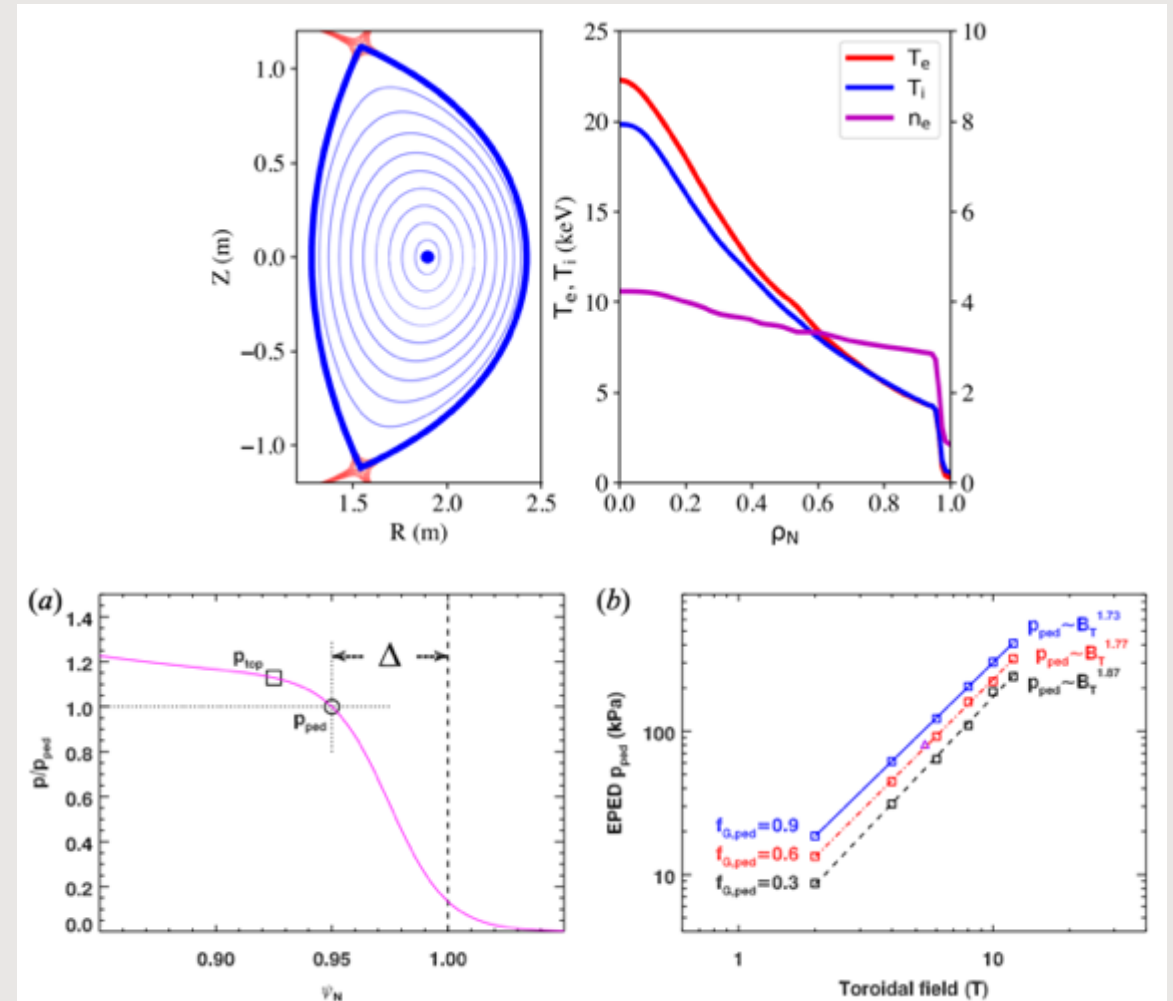
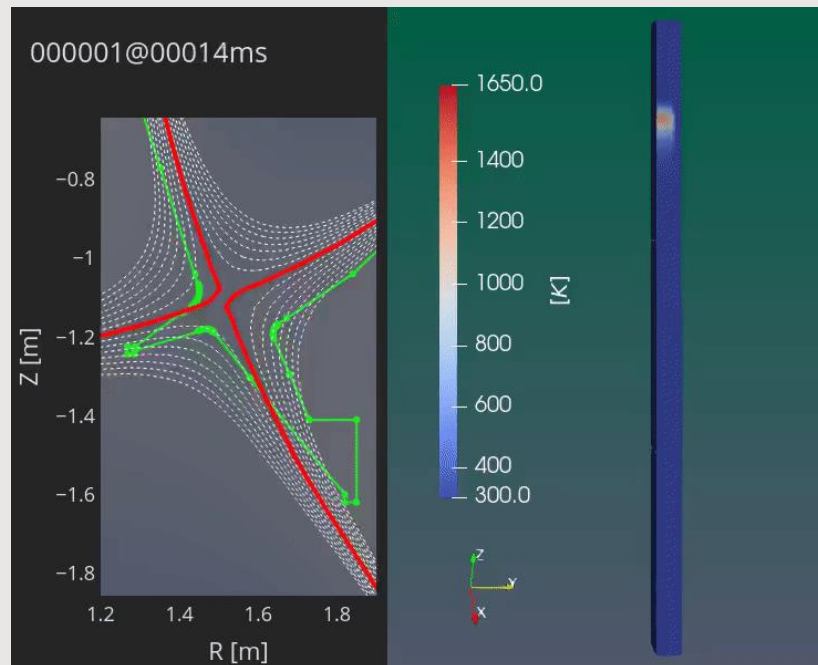
ITER DB4v5 from [Thomsen et al. 2002].





# SPARC Simulated with Best Tools

- Using first-principle simulations
  - Often supported by INFUSE grants
  - Core performance similar to empirical databases  $Q \sim 10$
- Divertor simulations used to design



Rodriguez-Fernandez, P., Howard, N., Greenwald, M., Creely, A., Hughes, J., Wright, J., . . . Sciortino, F. (2020). Predictions of core plasma performance for the SPARC tokamak. *Journal of Plasma Physics*, 86(5), 865860503. doi:10.1017/S0022377820001075

Hughes, J., Howard, N., Rodriguez-Fernandez, P., Creely, A., Kuang, A., Snyder, P., . . . Greenwald, M. (2020). Projections of H-mode access and edge pedestal in the SPARC tokamak. *Journal of Plasma Physics*, 86(5), 865860504. doi:10.1017/S0022377820001300

# SPARC Magnet Development Completed



- Non-insulated TF:
  - Demonstrated at 20T and scale of SPARC with ~identical winding pack
  - Showed high stability and novel operation predicted by simulation
  - Purposefully pushed to destruction to validate models – they agree
- Insulated CS+PF:
  - Low-AC loss 50kA 20T cable-based
  - Demonstrated at loads and strains of a high-field tokamak
  - Quench detection demonstrated
  - Now fabricating qualification coils



# SPARC Magnet Manufacturing Ramping Up



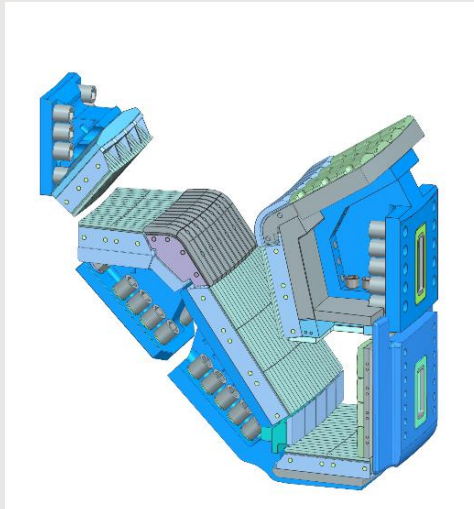
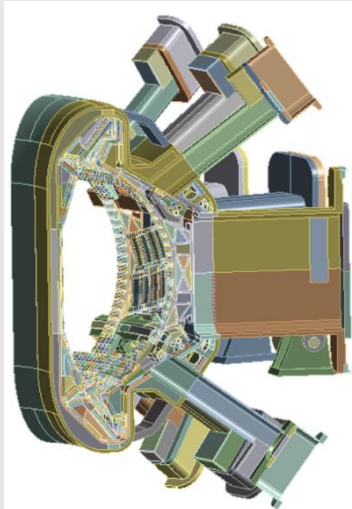
- All HTS ordered, 40% in warehouse
- TF now in production
  - 3<sup>rd</sup> generation automated production equipment qualified
  - First magnet by end of 2023
- CS+PF entering production soon
  - Automated cabling line coming online for ~20km of cables in SPARC
  - Winding machines being qualified
  - First magnet by end of 2023
- Each magnet tested at current and temperature prior to delivery





# SPARC Design Nearing Completion

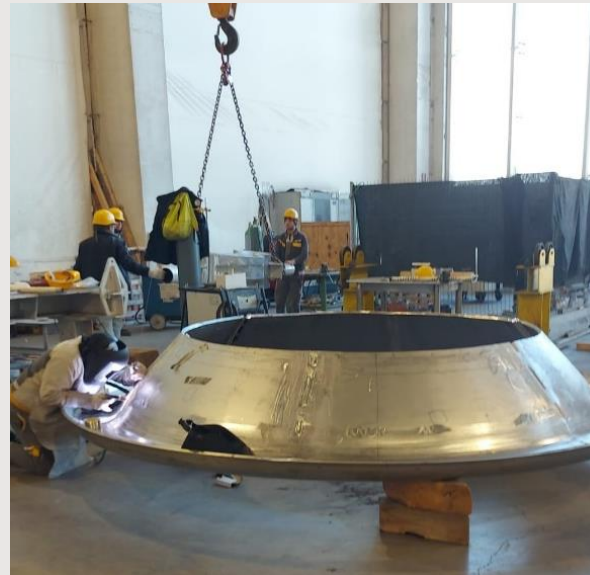
- Prototypes are continuing to provide input into design details
- Building and Plant are at final drawings
- Tokamak designs closing soon
- Design lessons learned will roll into ARC design



# SPARC Procurement ~60% Placed



- Long-lead procurements are into fabrication
  - Magnet components
  - Vacuum vessel
  - Cryostat
  - 20K Cryoplant
  - Tritium handling equipment
  - Motor-generator
  - Power supplies
  - Plasma facing materials
- Components arriving starting in Fall 2023 and throughout 2024



# SPARC Construction ~80% Complete



- Buildings erected over 2 years
- First fusion supporting components being readied for installation now
- Construction workforce rolls into SPARC assembly tasks



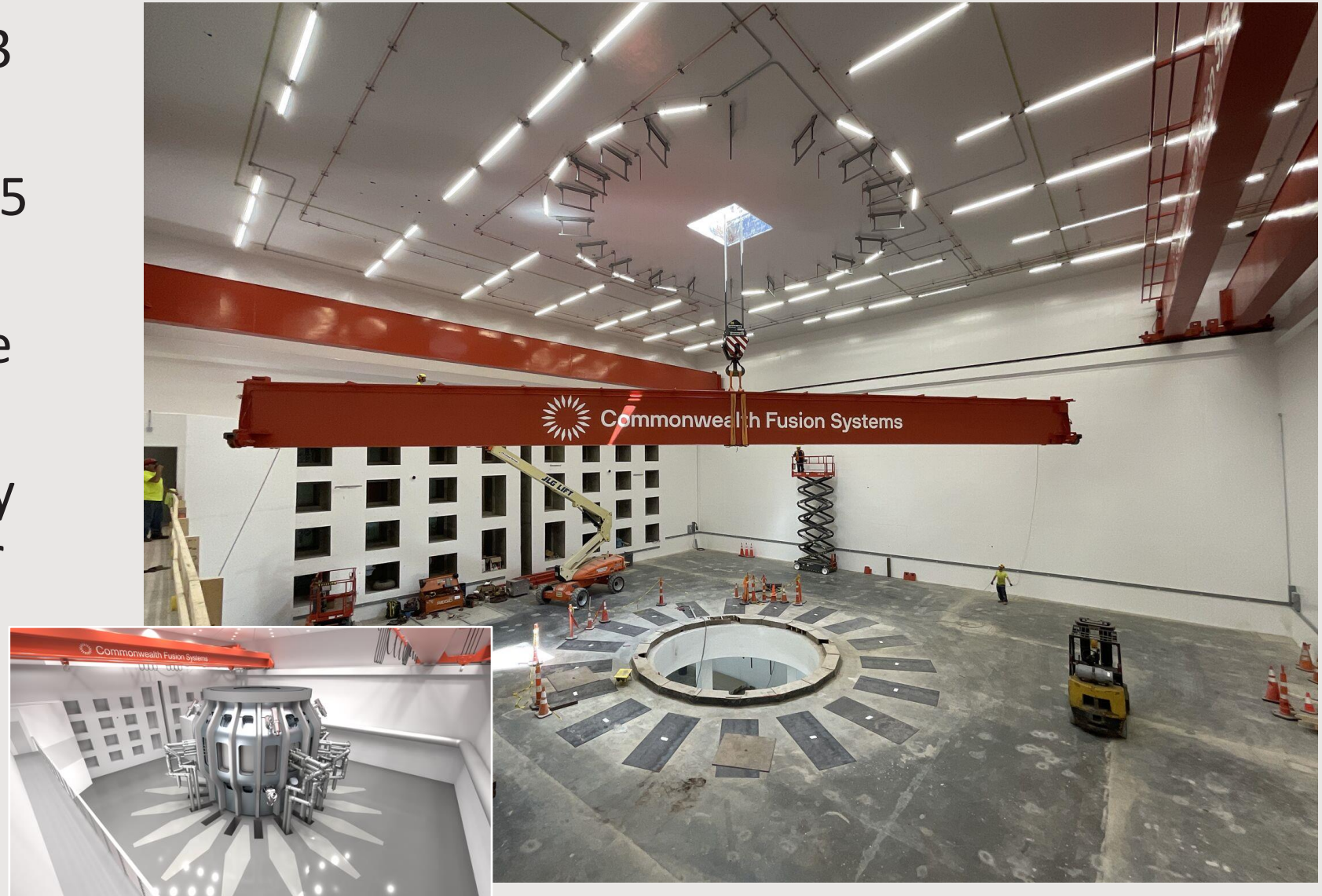
# SPARC Construction ~80% Complete



# SPARC Path to Completion



- Assembly starts in 2023 and completes in 2025
- First plasma in late 2025 or early 2026
- Campaign 1 will include tritium and  $Q > 1$
- Then campaigns to fully exploit the machine for ARC learning
- We are always looking for ways to accelerate



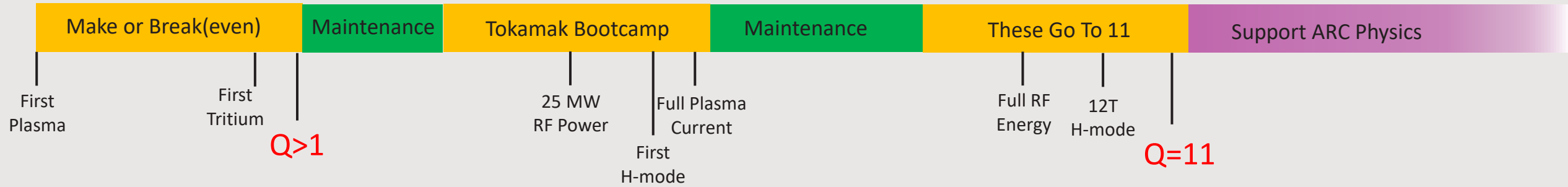
# SPARC Community Engagement Has Been Positive



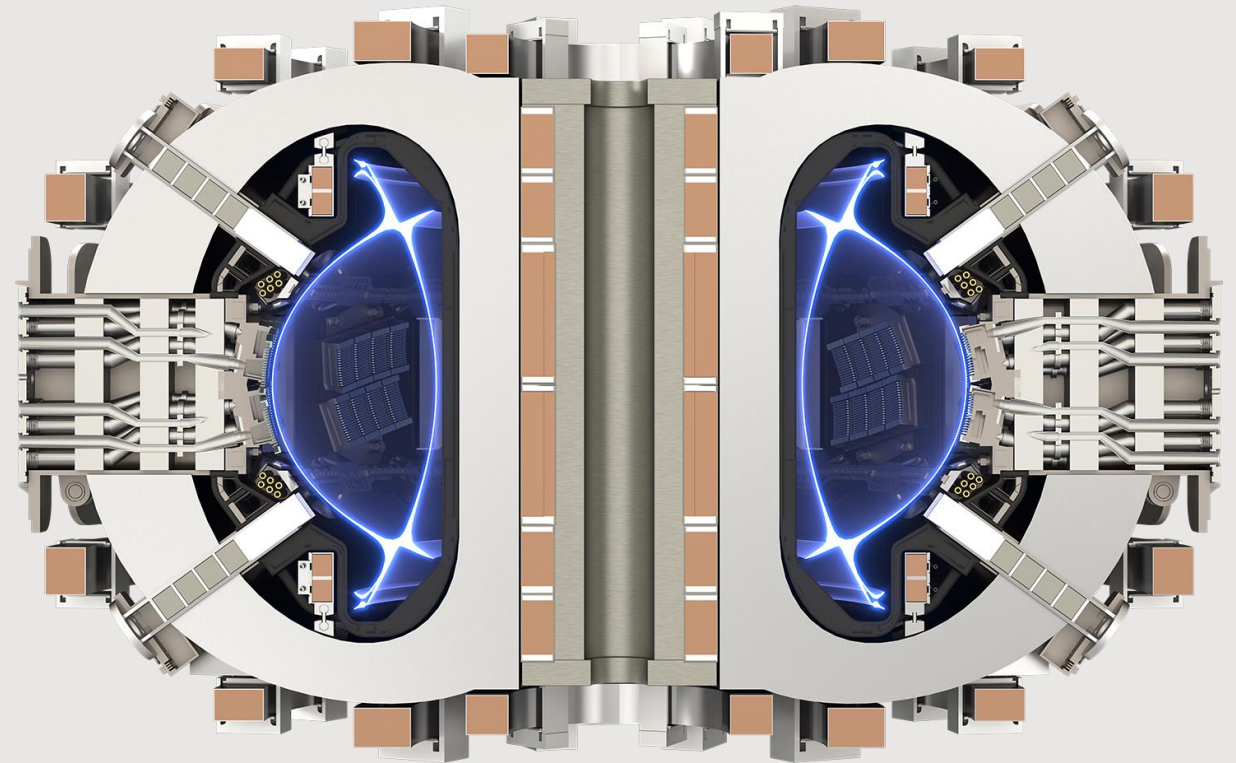
- Dialogue with community started ~1 year before any commitment
  - Only go somewhere where it is wanted
  - Community is excited about fusion and what we're doing
- Environmental permits in hand
  - Environmental baseline monitoring underway
- Radiological license is defined
  - First part of application going in this summer



# SPARC Will Be A Key Scientific Tool



- Will access key parameters never seen before
  - Burning, stationary, plasmas
  - Fusion neutron fluxes
  - Particle and heat fluxes
  - Fields and densities outside any other tokamak
- Can be upgraded
  - Port plugs are replaceable for new actuators and diagnostics



# SPARC Built on Collaboration

- Plan to contribute to plasma physics databases
- CFS already contributing to Open Source fusion codes
- Plan to collaborate on key scientific issues
  - MIT already deeply involved
  - Many other institutions involved
- A new platform for Public Private Partnerships



Commonwealth  
Fusion Systems



UK Atomic  
Energy  
Authority



COLUMBIA  
UNIVERSITY



EPFL



Politecnico  
di Torino



UNIVERSITY of  
ROCHESTER



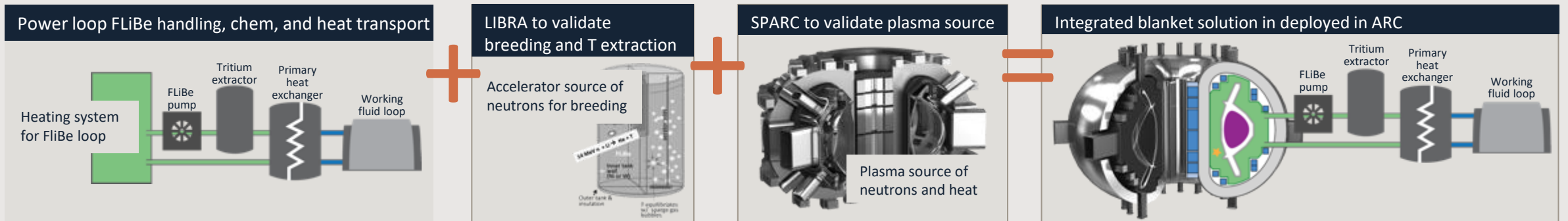
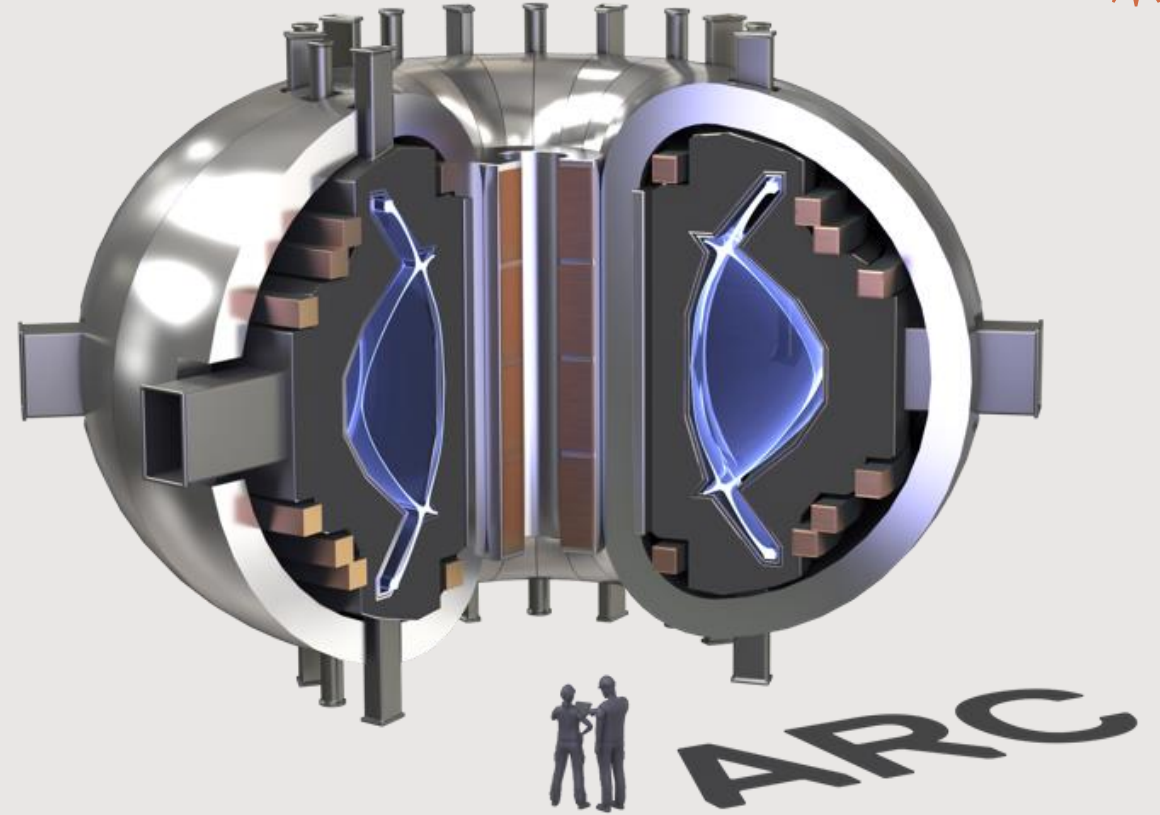
UNIVERSITY  
of York



# ARC Up Next



- ARC design starting in earnest
- Minimize the time between discovery on SPARC and implementation on ARC
- Sub-system R&D at a small level now but ramping up
- Searching for a site for the first ARC
- Goal is to roll into ARC as soon as possible as SPARC comes online



# Moving Fast



May 2023



Sept 2021





Commonwealth  
Fusion Systems